JC784 U.S. PTO
12/31/01

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PTO/SB/05 (08-00) (modified)
Approved for use through 9/30/2001, OMB 0651-0032
Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

JC784 U.S. PTO
10/036922
12/31/01

NEW UTILITY PATENT APPLICATION TRANSMITTAL

(only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket Number	18590-06192
First Named Inventor	Dennis W. Vance
Title	LIGHT TRANSMISSIVE FILTER HAVING ANISOTROPIC PROPERTIES AND METHOD OF FABRICATION
Express Mail Label No.	EL566299629US

APPLICATION ELEMENTS

1. [X] Fee Transmittal Form (in duplicate)
2. [ ] Applicant claims small entity status. See 37 CFR 1.27
3. [X] Specification — *Total Pages* 27
   (preferred arrangement set forth below)
   - Descriptive Title of the Invention
   - Cross Reference(s) to Related Case(s)
   - Statement Regarding Fed sponsored R & D
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawing(s)
   - Detailed Description
   - Claim or Claims
   - Abstract of the Disclosure
4. [X] Drawing(s) *(35 U.S.C. 113)* — *Total Sheets* 4
5. Oath or Declaration
   a. [X] New Declaration — *Total Pages* 2
      [X] Executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional with Box 18 completed)*
      i. [ ] DELETION OF INVENTOR(S)
      Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. [X] Application Data Sheet. See 37 CFR 1.76

ACCOMPANYING APPLICATION PARTS

7. [X] Assignment Papers (cover sheet & document(s))
8. [ ] Certified Copy of Priority Document(s) *(if foreign priority is claimed)*
9. [X] Power of Attorney or Authorization of Agent
10. [ ] 37 CFR 3.73(b) Statement
11. [X] Preliminary Amendment
12. [ ] Information Disclosure Statement & PTO-1449
    [ ] Copies of IDS Citation(s)
13. [X] Nonpublication Request under 35 U.S.C. 122 (b)(2)(B)(i). Applicant must attach form PTO/SB/35 or its equivalent
14. [X] Return Postcard
15. [ ] _____
16. [ ] _____
17. [ ] _____

ADDRESS TO:

Box Patent Application
Commissioner for Patents
Washington, D.C. 20231

18. **If a CONTINUING APPLICATION,** *check appropriate box and supply the requisite information below and in a preliminary amendment or in an Application Data Sheet under 37 CFR 1.76:*

[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No: ___/_____

Prior application information: *Examiner:* _____ *Group/Art Unit:* _____

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuing or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

19. CORRESPONDENCE ADDRESS

[X] *Customer Number and Bar Code Label*

00758

Name (Print/Type)	Albert C. Smith	*Registration No. (Attorney/Agent)*	20,355
Signature	Albert C. Smith	*Date*	12/31/01

PTO/SB/17 (10-01)(modified)
OMB 0651-0032
Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

0002/PTO(modified) Rev. 10/2001

U.S. Department of Commerce
Patent and Trademark Office

FEE TRANSMITTAL

TOTAL AMOUNT OF PAYMENT

Subtotal (1) + Subtotal (2) + Subtotal (3) = **($) 410.00**

Complete if Known	
Application Number	
Filing Date	December 31, 2001
First Named Inventor	Dennis W. Vance
Group Art Unit	
Examiner Name	
Attorney Docket Number	18590-06192

JC932 U.S. PTO 10/039622 12/31/01

METHOD OF PAYMENT

1. The Commissioner is hereby authorized to:

☐ Charge the indicated fees to the below mentioned deposit account.

☒ Charge any additional fee required under 37 CFR 1.16 - 1.21 or credit any over payments to the below mentioned deposit account. †

☐ Applicant claims small entity status See 37 CFR 1.27

Deposit Account Number: 19-2555
Deposit Account Name: FENWICK & WEST LLP

A Duplicate Copy of this authorization is attached

2. ☒ Payment Enclosed:
☒ Check ☐ Credit Card ☐ Other

FEE CALCULATION (fees effective 10/01/2001)

1. FILING FEE

Large Entity Fee Code/Fee	Small Entity Fee Code/Fee	Fee Description	Fee Due
101/$740	201/$370	Utility Filing	370
106/$330	206/$165	Design Filing	
108/$740	208/$370	Reissue	
114/$160	214/$80	Provisional Filing	
		SUBTOTAL (1)	**($) 370.00**

2. CLAIMS

Large Entity Fee Code/Fee	Small Entity Fee Code/Fee	Fee Description
103/$18	203/$9	Claims in excess of 20
102/$84	202/$42	Independent claims in excess of 3
104/$280	204/$140	Multiple dependent claim
109/$84	209/$42	Reissue independent claims over original patent
110/$18	210/$9	Reissue claims in excess of 20 and over original patent

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code/Fee	Small Entity Fee Code/Fee	Fee Description	Fee Due
105/$130	205/$65	Surcharge - late filing fee or oath	
127/$50	227/$25	Surcharge-late provisional filing fee or cover sheet	
147/$2,520	147/$2,520	For filing a request for reexamination	
115/$110	215/$55	Extension for response within first month†	
116/$400	216/$200	Extension for response within second month†	
117/$920	217/$460	Extension for response within third month†	
118/$1,440	218/$720	Extension for response within fourth month†	
128/$1,960	228/$980	Extension for response within fifth month†	
119/$320	219/$160	Notice of Appeal	
141/$1,280	241/$640	Petition to revive unintentionally abandoned application	
142/$1,280	242/$640	Utility Issue Fee (Or Reissue)	
143/$460	243/$230	Design Issue Fee	
122/$130	122/$130	Petitions to the Commissioner	
126/$180	126/$180	Submission of Information Disclosure Statement	
179/$740	279/$370	Request for Continued Examination (RCE)	
581/$40	581/$40	Recording each patent assignment per property (times number of properties)	40
146/$740	246/$370	Filing a submission after final rejection (37 CFR 1.129(a))	
149/$740	249/$370	For each additional invention to be examined (37 CFR 1.129(b))	
		Other fee *(specify)*:	
		Other fee *(specify)*:	
		SUBTOTAL (3)	**($) 40.00**

For	(Col. 1) No. of Existing Claims		(Col. 2) Highest No. Previously Paid For		(Col. 3) Extra**		Fee		Fee Due
TOTAL	16	minus*	20 or 0	=	0	x		=	0
INDEP	3	minus*	3 or 0	=	0	x		=	0
[ ] First presentation of multiple dependent claim								=	0

* *Subtract the greater number of Col. 2*
** *If the difference between Col. 1 and Col. 2 is less than zero, then enter "0" in Col. 3*

SUBTOTAL (2) **($) 0**

SUBMITTED BY		Complete (if applicable)	
Typed or Printed Name	**Albert C. Smith**	Reg. Number	**20,355**
Signature	Albert C. Smith	Date	12/31/01

† *Request for Extension of Time per 37 CFR 1.136 (a)(3) made hereby*

PTO/SB/35 (11-00)
Approved for use through 10/31/2002. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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NONPUBLICATION REQUEST UNDER 35 U.S.C. 122(b)(2)(B)(i)

First Named Inventor	Dennis W. Vance
Title	LIGHT TRANSMISSIVE FILTER HAVING ANISOTROPIC PROPERTIES AND METHOD OF FABRICATION
Atty Docket Number	18590-06192

jc932 U.S. PTO 10/039622 12/31/01

I hereby certify that the invention disclosed in the attached application **has not been and will not be** the subject of an application filed in another country, or under a multilateral agreement, that requires publication at eighteen months after filing. I hereby request that the attached application not be published under 35 U.S.C. 122(b).

12/31/01
Date

A. C. Smith
Signature

Albert C. Smith, Reg. No. 20,355
Typed or printed name/Registration Number

This request must be signed in compliance with 37 CFR 1.33(b) and submitted with the application **upon filing**.

Applicant may rescind this nonpublication request at any time. If applicant rescinds a request that an application not be published under 35 U.S.C. 122(b), the application will be scheduled for publication at eighteen months from the earliest claimed filing date for which a benefit is claimed.

If applicant subsequently files an application directed to the invention disclosed in the attached application in another country, or under a multilateral international agreement, that requires publication of applications eighteen months after filing, the applicant **must** notify the United States Patent and Trademark Office of such filing within forty-five (45) days after the date of the filing of such foreign or international application. **Failure to do so will result in abandonment of this application (35 U.S.C. 122(b)(2)(B)(iii)).**

Burden Hour Statement: This collection of information is required by 37 CFR 1.213(a). The information is used by the public to request that an application not be published under 35 U.S.C. 122(b) (and the PTO to process that request). Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This form is estimated to take 6 minutes to complete. This time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, Washington, DC 20231.

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Fax One:: 650-494-1417

APPLICATION INFORMATION

Title Line One:: LIGHT TRANSMISSIVE FILTER HAVING ANISOTR
Title Line Two:: OPIC PROPERTIES AND METHOD OF FABRICATIO
Title Line Three:: N
Total Drawing Sheets:: 4
Formal Drawings?:: No
Application Type:: Utility
Docket Number:: 18590-06192
Secrecy Order in Parent Appl.?:: No

REPRESENTATIVE INFORMATION

Registration Number One:: 20355
Registration Number Two:: 41015

Source:: PrintEFS Version 1.0.1

IN THE UNITED STATES
PATENT AND TRADEMARK OFFICE

APPLICANTS:	Dennis W. Vance et al.
APPLICATION NO.:	Unassigned
FILING DATE:	December 31, 2001
TITLE:	LIGHT TRANSMISSIVE FILTER HAVING ANISOTROPIC PROPERTIES AND METHOD OF FABRICATION
EXAMINER:	Unassigned
GROUP ART UNIT:	Unassigned
ATTY. DKT. NO.:	18590-06192

CERTIFICATE OF MAILING			
I hereby certify that this correspondence, including the enclosures identified above, is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Commissioner for Patents, Washington, D.C. 20231 on the date shown below. If the Express Mail Mailing Number is filled in below, then this correspondence is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service pursuant to 37 CFR 1.10.			
Signature:	A. C. Smith		
Typed or Printed Name:	**Albert C. Smith, Reg. No. 20,355**	Dated:	12/31/01
Express Mail Mailing Number (*optional*):	**EL566299629US**		

BOX PATENT APPLICATION
COMMISSIONER FOR PATENTS
WASHINGTON, DC. 20231

PRELIMINARY AMENDMENT

Sir:

Prior to the examination of the patent application identified above, please amend the application by including the new claims 11-16. All of the claims in this application are set forth as follows:

1. A light filter comprising:

a first layer of substantially opaque material including front and back surfaces;

a plurality of light transmissive beads disposed in a single-layer array within the first layer of opaque material with first portions of the beads protruding through the front surface of the first layer to receive incident light and with remaining portions of the beads not disposed within the first layer penetrating through the back surface of the first layer of opaque material to form light transmissive apertures therethrough; and

a second layer of light-dispersing material having asymmetrical dispersion characteristics along orthogonal axes, the second layer being disposed relative to the beads and first layer to disperse light incident thereon that is normal to the orthogonal axes for enhancing light transmission within the output angle along one of the orthogonal axes relative to light transmission within the output angle along another of the orthogonal axes.

2. A light filter according to claim 1 in which the second layer is disposed to receive light emanating from the apertures.

3. A light filter according to claim 1 in which the second layer is interposed between incident light and the front surface of the first layer.

4. The light filter according to claim 2 including a layer of transparent lenses overlaying the first portion of beads having radius R protruding through the

front surface of the first layer, said layer of lenses including curved surfaces disposed to receive incident light and overlaying the first portion of the beads at selected radii of curvature relative to radius R of the beads.

5. The light filter according to claim 3 in which the second layer includes elongated prismatic lenses oriented along one of the orthogonal axes, and including surfaces oriented normal to incident light and sloping surfaces oriented skewed to incident light, the second layer being interposed between incident light and the first portion of beads protruding from the opaque layer for enhancing light transmission within one output angle along a horizontal axis relative to light transmission within another output angle along the vertical axis.

6. The light filter according to claim 2 in which the second layer includes elongated prismatic lenses oriented in substantial alignment with a vertical axis as one of the orthogonal axes, and including surfaces oriented normal to incident light and sloping surfaces oriented skewed to incident light, the second layer being disposed to receive light emanating from the apertures for enhancing light transmission within one output angle along the horizontal axis relative to light transmission within another smaller output angle along the vertical axis.

7. The light filter according to claim 5 in which the sloping surfaces include multiple facets at different sloping angles.

8. The light filter according to claim 5 in which the sloping surfaces

adjacent the surfaces normal to incident light slope at different angles.

9. A light filter comprising:

a first layer of substantially opaque material including front and back surfaces;

a plurality of light-transmissive, substantially spherical beads disposed in a single-layer array within the first layer of opaque material with first portions of the beads protruding through the front surface of the first layer to receive incident light and with remaining portions of the beads not disposed within the first layer penetrating through the back surface of the first layer of opaque material to form light transmissive apertures therethough;

a support layer of transparent material disposed to receive light emanating through the apertures; and

a prism layer disposed relative to the first portion of the beads and the support layer to disperse light supplied thereto asymmetrically along orthogonal axes, the prism layer including a plurality of aligned prisms each including a plurality of substantially planar surfaces oriented along a substantially vertical axis, the prisms dispersing light passing therethrough within a greater angle along the horizontal axis than along the vertical axis.

10. The light filter according to claim 9 in which the prism layer is a film.

11. (New) A light filter comprising:

a first layer of substantially opaque material including front and back surfaces;

a plurality of light-transmissive, substantially spherical beads disposed in a single-layer array within the first layer of opaque material with first portions of the beads protruding through the front surface of the first layer to receive incident light and with remaining portions of the beads not dsposed within the first layer penetrating through the back surface of the first layer of opaque material to form light transmissive apertures therethough;

a support layer of transparent material disposed to receive light emanating through the apertures; and

a second layer of substantially transparent material interposed between the back surface of the first layer and the support layer, with said remaining portions of the beads protruding into the second layer to increase the size of the light transmissive apertures through the first layer.

12. (New) The light filter according to claim 11 comprising:

a second layer of substantially transparent material interposed between the back surface of the first layer and the support layer, with said remaining portions of the beads protruding into the second layer to increase the size of the light transmissive apertures through the first layer.

13. (New) The light filter according to claim 12 in which the beads have a radius R, and the thickness of the second layer is not greater than R.

14. (New) The light filter according to claim 13 in which the thickness of the second layer is about ten percent (10%) of R.

15. (New) The light transmissive filter according to claim 11 in which the material of the beads has a selected index of refraction; and

the material of the second layer has an index of refraction that is different from the selected index of refraction of the beads.

16. (New) The light filter according to claim 11 in which the material of the beads has a selected index refraction; and

the material of the second layer has an index of refraction that is not greater than the selected index of refraction of the beads.

REMARKS

Applicants are submitting additional claims to cover the invention with the scope and breadth of coverage to which they believe they are entitled.

Favorable action is solicited.

Respectfully submitted,
DENNIS W. VANCE ET AL.

Dated: 12/31/01

By: A. C. Smith

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LIGHT TRANSMISSIVE FILTER HAVING ANISOTROPIC PROPERTIES AND METHOD OF FABRICATION

Field of the Invention:

[0001] This invention relates to the field of light filters, and more particularly to light filters that exhibit asymmetrical dispersion of light perpendicular to direction of propagation.

Background of the Invention:

[0002] Rear projection screens and light diffusers include light filters which provide an optically dispersing medium for transmitting light from an image source on one side of the screen to a viewer on the opposite side of the screen. A basic refractive light filter has been described in U.S. Pat. No. 2,378,252, which includes a refracting lens system as its principal component. The refracting lens system comprises an array of spherical transparent beads embedded in an opaque binder layer and mounted on a transparent support material. Certain known light filters orient the bead layer toward the image source and the transparent support material toward the viewers. (See, for example, U.S. Patent No. 5,563,738).

[0003] The opaque binder layer affixes the beads to the support material, reduces the reflectivity of the filter, and reduces the amount of light transmitted

through the interstices between the beads of the lens system. Light from an image is refracted by the beads and dispersed to the viewer through a transmission area of the beads. This transmission area includes an aperture about the point of contact between the bead and support material and the area surrounding this point where the opaque binder layer is too thin to absorb the refracted light.

[0004] Rear projection screens and light diffusers are characterized by their ambient light rejection, resolution, gain, and contrast as properties which are determined by the structure and composition of the component materials. For example, the gain which is a measure of the intensity of transmitted light as a function of the viewing angle, is determined primarily by the index of refraction of the spherical beads and the surrounding medium. Similarly, the ambient light rejection and contrast of the light filter are determined largely by the opacity of the binder layer. The resolution of the screen is determined by the size of the beads used and how they pack together in the lens system.

[0005] However, the interdependence of certain optical properties and their dependence on the properties of component materials, limit optimization of the optical properties of basic refractive light filters. For example, if the opacity of the binder layer is increased to enhance the ambient light rejection of the viewing surface, transmission of refracted image light through the binder layer in the transmission area of the bead will be reduced. In addition, the range of indices of

refraction of available materials also limits the performance of such filters. Such interdependencies and material limitations hamper the performance of basic refractive filters.

Summary of the Invention:

[0006] A multi-layer light filter in accordance with the present invention includes a single layer of glass or resin beads supported in an opaque layer and an additional contiguous light-dispersing support or backing layer that exhibits asymmetrical light-dispersing properties along axes perpendicular to the direction of propagation. This structure of optical components enhances the diffusion or scattering of light along one axes, for example the horizontal axis, and without changing the diffusion or scattering of light along an orthogonal axis, for example, the vertical axis. Such a structure promotes wider viewing angles as viewed along one (i.e., the horizontal) axis from the light output side of the support layer. Such structure also leaves unchanged viewing angles, as viewed along the other (i.e., vertical) axis from the light output side of the support layer.

[0007] In accordance with another embodiment of the present invention, the gain of the structure that may be altered by the addition of a layer of transparent resin on the incident light side of the structure to cover all or part of the portion of

the beads protruding from the opaque layer in substantial surface conformity with the contour of the protruding beads.

[0008] The transparent resin layer provides additional gain control by increasing the incident area of light transmitted through a bead and by replacing the air/bead interface with air/resin and resin/bead interfaces at which both the refraction and reflection of image light can be separately adjusted. Selecting the relative indices of refraction, contour, and the thickness of the transparent resin forming the conformal layer as well as the index of refraction of the beads controls refraction and reflection at the resin/bead interface. A thin layer of transparent resin is effective to alter the shape of the protruding surfaces of the beads. Also, a thin transparent layer may be disposed between the contact points of the beads with the support layer and the opaque binder layer to alter the exit apertures of the beads for enhancing transmission therethrough of refracted light.

[0009] Additionally, the support layer may exhibit asymmetric dispersion of light by different amounts and angles in one orientation than in an orthogonal orientation. This facilitates expansion of the viewing angle, for example, along the horizontal axis compared with narrower viewing angle along the vertical axis. Such support layer may form the support or backing layer contiguous the single layer of beads, or may supplement a transparent support layer in a more rigid

structure to provide substantially the same asymmetrical scattering oflight passing through the light filter assembly.

Description of the Drawings:

[0010] Figure 1 is a sectional view diagram of one embodiment of the present invention, illustrating the direction of light propagation;

[0011] Figure 2 is a sectional view illustrating the refraction of light rays by spherical beads in the embodiment of Figure 1;

[0012] Figure 3 is a pictorial diagram illustrating asymmetrical light dispersion through the support layer in the embodiment of Figure 1;

[0013] Figure 4 is a graph illustrating typical screen gain associated with a conventional beaded light filter as a function of index of refraction of the bead material;

[0014] Figure 5 is a graph illustrating the intensity of asymmetric dispersion of light through the support layer in the embodiment of Figure 1;

[0015] Figure 6 is a sectional view of another embodiment of light filter in accordance with the present invention;

[0016] Figure 7 is a graph illustrating asymmetric light diffusion through the embodiment of a light filter illustrated in Figure 6;

[0017] Figure 8 is a sectional view of another embodiment of the light filter including an intermediate transparent layer for enhanced light transmission through the filter;

[0018] Figure 9 is a sectional view of another embodiment of the present invention, showing a structure that can be used to enhance the gain along one axis relative to another orthogonal axis;

[0019] Figure 10 and Figure 11 are sectional views of prismatic lenses fabricated as microgrooves.

Detailed Description of the Invention

[0020] Referring now to Figure 1, there is shown a sectional view of a segment of a light filter **10** according to one embodiment of the present invention. A support layer **12** having asymmetric light dispersing properties, as more fully described later herein, contacts a plurality of spherical glass or resin transparent beads **14** that are oriented substantially in contiguous array one layer deep on the support layer **12**. The interstices between beads **14**and the support layer **12** are filled with an opaque binder **16** which binds the beads **14** to the support layer **12** and inhibits the passage of incident light **15** through the filter otherwise than through the front center of the beads **14**

[0021] Light **38** that is approximately collimated from an effectively distant image source (not shown) is incident on filter **10** at back surfaces **36** of beads**14**

and back surface **19** of opaque binder layer **16** between the beads. These surfaces define an incident or image side of light filter **10**. Outer surface **18** of the support layer **12** defines a front or viewing side of light filter **10** through which viewers observer the transmitted image light. Thus, light incident on beads **14** is refracted, transmitted through the beads **14** and the associated transmission apertures**34**, and is asymmetrically dispersed to viewers through the support layer **12**. Light **38** incident on back surface **19** of binder layer **16** between beads **14**is absorbed to reduce transmission of this light through the filter assembly**10**.

[0022] Referring now to FIG. **2**, there is shown a diagram of the paths followed by refracted light rays **22**, **24**, **26**, **28** incident on back surface **36** of bead**14** at various distances from optic axis **30**. Substantially collimated light rays**22**, **24**, **26**, **28** are refracted toward optic axis **30** by an angle Ψ that increases with the distance between a point of incidence **31** and optic axis **30** Angle Ψ also increases with the index of refraction of beads **14**. Refracted light rays **22**, **24**, **26**, **28** are directed through transmission aperture **34**, which includes the point of contact between bead **14** and support layer **12** as well as the surrounding area where intervening opaque binder layer **16** is too thin to absorb refracted light rays**22**, **24**, **26**, **28**. In contrast, non-collimated or refracted ray **29** strikes the front surface of bead **14** and tend to be refracted to outside of transmission aperture **34** and are absorbed by opaque binder layer **16**.

[0023] Refracted rays **22, 24, 26, 28** diverge after passing through the transmission aperture **34** of bead **14** and disperse through the support layer **12** over a larger range of horizontal viewing angles and a narrower range of vertical viewing angles. The collective action of beads **14** and support layer **12** in dispersing transmitted light intensity at various horizontal and vertical viewing angles relative to a normal axis **11** of filter output surface **18** results in the gain profile of the filter. High gain light filters generally transmit image light in a narrow angular distribution about a normal viewing axis, whereas low gain filters generally transmit image light in broad distributions about the normal viewing axis. The optimum gain for such light filters depends upon its intended use, and is selected in part by choosing the optical material for beads **14** having an appropriate index of refraction, as later discussed herein.

[0024] Referring to the graph of FIG. 4, there are plotted gain profiles **40, 42, 44** for basic refractive light filters **10** comprising beads **14** having indices of refraction of 1.5, 1.7, and 1.9, respectively. The gain at 0° with respect to normal **11** is greatest for low index beads **14** and decreases with increasing index of refraction. The greater refractive power of high index beads **14** refracts transmitted rays **22, 24, 26, 28** more significantly than low index materials, and such rays subsequently diverge over a wider range of horizontal or vertical viewing angles from the normal axis **11** and are less focused along the normal axis **11**.

[0025] In addition to gain, light filters **10** are characterized by their resolution, contrast, and ambient light rejection. For these filters, it is generally desirable to have both high resolution and high ambient light rejection. The resolution of light filter **10** is determined by the size of beads **14**, since the packing density of beads **14** on support layer **12** determines the density of transmission apertures **34** on this surface. This property can generally be maximized by constructing filters **10** using the smallest diameter beads **14** available, typically of approximately 25-100 microns in diameter. The minimum practical size of beads **14** sdected may be dictated by variations in the quality and properties of available beads **14**

[0026] Ambient light rejection measures how well ambient light incident on the viewing surface of a light filter is absorbed or transmitted relative to the amount re-dispersed back toward the viewer. This property depends primarily on the reflectivity of the front surface of the support layer **18**, the opacity of binder layer **16** and the index of refraction of beads **14**. Ambient light reflected into viewers' eyes from filter **10** can significantly impair the quality of an image by reducing the contrast.

[0027] In the filter assembly **10** illustrated in Figure 1, ambient light incident on the viewing surface **18** may be reflected at the interfaces between: a) the opaque binder layer **16** and support layer **12**; b)the beads **14** and opaque binder layer **16**; and c) beads **14** and air at incident surface **36**. Of these, the air-bead

interface may be most significant because the indices of refraction of support layer **12**, opaque binder layer **16**, and beads **14** can be made more nearly equal to minimize reflections from the first two interfaces. Ambient light rejection in the filter **10** of Figure 1 is affected by opacity of binder layer **16**. However, increasing the opacity of binder layer **16** to improve ambient light rejection decreases the amount of image light transmitted through the transmission apertures **34** around the point of contact between beads **14** and support layer **12**.

[0028] Referring now to Figure 3, there is shown a pictorial diagram of the light dispersing properties of the support layer **12**. This layer **12** is typically formed of polymer material that is commercially available in sheets a few mils thick and promotes asymmetrical dispersion of incident light along orthogonal axes. Other forms and types of asymmetric dispersing layers may be used that include holographic dispersing films, micro formed lenticular arrays abraded films and similar materials. The incident light **17** may be approximately collimated and may enter the layer **12** approximately normal to an incident surface of the layer. Such incident light is dispersed predominantly along one axis **21**, for example, along the horizontal axis, and significantly more weakly along an orthogonal (e.g. vertical) axis **23**.

[0029] Referring now to the graph of Figure 5, the asymmetrical or anisotropic optical properties of the support layer **12** are illustrated as being significantly

different along different axes in that transmitted light is dispersed along the vertical axis from an initial gain of about 10 (for normal incident illumination and on-axis viewing) to half-gain level at about 7° off-axis viewing. In contrast, the transmitted light is dispersed along the horizontal axis to half-gain level at about 18° off axis viewing.

[0030] Referring now to Figure 6, there is shown another embodiment of a light filter **120** of the present invention comprising a single-layer array of light transmissive beads **14** structurally supported in an opaque binder layer **16** having a surface **19** through which the beads **14** protrude to receive substantially collimated light **220** from an image source (not shown), and having a substantially flat interface surface **27** at which the beads **14** contact the support layer **12** of anisotropic dispersing properties. This allows transmission of the light **220** through a plurality of transmission apertures **34** and through the support layer **12** for viewing within different horizontal and vertical viewing angles. The beads **14** each have a radius about equal to a selected value R. The light filter **120** includes the transparent support layer **12** affixed to the surface **27** of the opaque binder layer **16**, with the filter surface **18** oriented toward the viewer (not shown). The light filter **120** also includes an additional conformal layer of light transmissive material **128** disposed over the protruding beads **14** to a substantially uniform thickness between about 0.1R and 1.0R, where such thickness is measured normal to the

spherical surfaces **36** of the beads **14**. This conformal layer **128** can also cover the surface **19** of an opaque binder layer **16** between substantially contiguous beads **14**.

[0031] The conformal layer **128** defines a plurality of lenses **131** for controlling dispersion of incident light and increasing the transmittance of the light filter **120**. Each such lens **131** is disposed on the protruding surface **36** of a bead **14** and has a substantially spherical or curved incident surface **129** with a radius of curvature about 1.1 to 2 times the radius of the bead **14** or an average thickness around the beads of about .1 to 1 times the radius of thebeads **14**.

[0032] The conformal layer **128** presents increased incident surface to incoming light 220 and functions as a preliminary stage of convergent refraction of light **220** from the image source (not shown) into the beads **14**. This allows a greater portion of incident light to enter into the beads **14**, and such light **220** so converged is incident on the protruding surfaces **36** of the beads**14** above the opaque layer **16** at angles that allow a greater percentage of the light **220** to enter the beads **14** and propagate into the transmission apertures **34** of the beads **14**. Light emanating from the transmission apertures **34** is then asymmetrically or anisotropically dispersed by the support layer **12** for viewing through different horizontal and vertical viewing angles relative tothe axis **11** that is normal to the viewing surface **18**. Thus, a greater percentage of the light **220**striking the back surfaces **36** of the beads **14** is transmitted through the filter surface **18** than is

typically feasible with conventional single-layer light filters, which have a typical transmittance within the horizontal viewing angles to about 35 percent.

[0033] The conformal layer **128** also reduces the index of refraction mis-match (n_{beads}/n_{medium}) at the rear surface of the screen. Reducing this index mis-match reduces reflection of the light **220** off the surfaces **36** of the beads **14**, and increases the transmittance of the light filter **120**. Typical index of refraction of the bead material is about 1.4 to 1.9.

[0034] The gain of light filter **120** can further be controlled by the degree of curvature of the incident surface **129** of the conformal layer **128**. These properties of the present invention beneficially prevent excessive loss of image light intensity caused by reflection, as in conventional single-layer light filters. Adjustment of the dispersion of light through various angles Φ relative to the axis **11** that is normal to the viewing surface **18** of the support layer **12** in light filter **120** can also be achieved by appropriately selecting the index of refraction of the light-transmissive material of the conformal layer **128**. Heat and pressure can be applied to selectively shape the incident surface **129** of the conformal layer **128** for improved operation of the light filter **120**. For example, the transmittance of the light filter **120** can be increased by reducing the radius of curvature of the incident surface **129** of this layer **128**, as illustrated and described in greater detail later herein with reference to Figure 8.

[0035] Referring to the graph of Figure 7, the optical characteristics of the light filter illustrated in Figure 6 show significant asymmetrical gains in vertical and horizontal orientations. Specifically, initial gain (for normal incident illumination and on-axis viewing) diminishes significantly with viewing angle from on-axis orientation along the vertical axis, but diminishes less significantly with viewing angle from on-axis orientation along the horizontal axis. In one embodiment of the light filter of Figure 6, the gain diminishes to one-half of the initial level at approximately 18° off axis viewing along the vertical axis, and diminishes to one half of the initial gain at approximately 38° off axis viewing along the horizontal axis with the asymmetry of the viewing angles maximized at about 36°.

[0036] Referring now to Figure 8, there is shown another embodiment of a light filter **122** according to the present invention in which an array of light transmissive beads **14** one layer thick are substantially contiguously supported in an opaque binder layer **16** having an incident surface **19**through which the beads **14** protrude to receive substantially collimated light **320, 322** from an image source (not shown), and having a substantially flat front surface **27** through which the beads **14** protrude. Large transmission apertures **34**allow transmission of the light **320, 322** therethrough that is anisotropically diffused along horizontal and vertical viewing axes by the support layer **12.** This embodiment of light filter **122** according to the present invention includes a thin layer **15** of transparent material

to a thickness of about 10% of the radius R of the beads to facilitate formation of larger transmission apertures **34** than can be achieved through point contact alone of the beads **14** with the support layer **12**. The thickness of the transparent layer **15** (typically, to not greater than R) control the sizes of the transmission apertures **34** and therefore the gain of the filter. The index of refraction of the material forming transparent layer **15** may be generally equal to or less than the refractive index of the beads for reducing the reflectance of the entire assembly by graded index changes.

[0037] The light filter **122** also includes a conformal layer **128**of light transmissive material disposed on the incident surfaces **36** of the beads **14** and surface **19** of an opaque binder layer **16**. The additional conformal layer **128** defines a substantially spherical or parabolic lens**131** behind each bead **14,** with local points or centers of curvature **342** disposed forward in the direction toward the source of incident light relative to the centers of curvature **340** of the beads**14**. The layer **128** thus has a non-uniform thickness as measured normally to the spherical protruding surfaces **36** of the beads **14**.

[0038] The conformal layer **128** provides a preliminary stage of convergent refraction of the incident light **320, 322** into the beads **14.** Further, it is believed that displacing the centers of curvature **342** or the focal points of the incident surface **129** of layer **128** forward in the direction toward the source of incident

light relative to the centers of curvature **340** of the beads 14 increases convergence of such light **320**, **322** into the beads **14**, and converges such light into the beads **14** nearer to the ideal angles for refraction of such light **320**,**322** through the transmission apertures **34**. This filter assembly is believed to exhibit transmittance of up to about 60 percent.

[0039] The support layer **12** diffuses light emanating through transmission apertures **34** through different vertical and horizontal viewing angles relative to axis **30** normal to the viewing surface **18**, as previously described with reference to Figure 3. Alternatively, the support layer **12** may comprise a thin film of such anisotropical dispersing material, as previously described with reference to Figure 3, disposed on a thick layer of transparent material (on either side) to form a composite support layer for improved sturdiness of the light filter **120**. The support layer **12** is affixed to the thin transparent layer **15** which, in turn, is affixed to the surface **27** of the opaque binder layer **16**, with the viewing surface **18** oriented toward the viewer (not shown).

[0040] The index of refraction of the beads **14** is preferably selected to be from 1x to 1.3x index of refraction of the conformal layer **128**for increasing transmission of image light into the beads **14**. Suitable materials for the conformal layer **128** include polymethylmethacrylate and thermoplastic polyurethane (TPU), and similar clear thermoplastic materials. For example, a conformal layer **128**with

an index of refraction of about 1.5 can be fabricated for either of these two materials, and the beads **14** can be fabricated from glass or resinous material selected with an index of refraction in a range between about 1.5 and 1.94. The conformal layer **128** beneficially reduces the difference, or mis-match in indices of refraction encountered by light **320, 322** at the interface with the incident surface **36** of the beads **14**. This increases the transmittance of the beads **14.** Gain control can also be provided, by controlling the thickness and/or selectively shaping the incident surface **129** of the conformal layer **128** in the manner described above. In an alternative embodiment of the present invention, a layer of anisotropic or asymmetrical light diffusing material of the type previously described herein with reference to layer **12** may be use to asymmetrically disperse the incident light over a greater angle along the horizontal axis than along the vertical axis.

[0041] One process of the present invention for making light filter **122**of the embodiment illustrated in Figure 8 uses an opaque binder such as thermoplastic resin uniformly mixed with a colorant such as carbon black, a plurality of light transmissive beads **14** each of radius R, and a thin layer **15** of transparent material having a uniform thickness selected between about 0.1R and 0.5R, and a support layer **12** of anisotropically diffusing film **12**. The opaque binder is selected to have a viscous unset state and substantially rigid set state, and the thin transparent material in layer **15** is selected to have a deformable semi-viscous unset state and

substantially rigid set state. The process includes depositing a layer of the opaque binder in the unset state on the thin transparent layer **15**which is disposed on the incident surface of the asymmetrical diffusing support layer to a total thickness above the support layer **12** that is about 0.3 to 0.8 R. The plurality of light transmissive beads **14** are arranged in a single layer array on the surface **19** of the opaque binder to then penetrate the plurality of light transmissive beads **14**into the layer of opaque binder **16** and through the thin layer **15** to the support layer **12** The opaque binder layer **16** is then activated into the set state for supporting the light transmissive beads **14** in position with the transmission apertures **34** of the beads **14** in contact with the asymmetrical diffusing layer **12** A layer of light transmissive material **128** in the unset state is disposed on protruding surfaces **36** of the beads **14**, pressure is applied to the layer of light transmissive material**128** to substantially conform the layer to the shapes of protruding portions of the beads **14** and laminate the conformal layer to the beads **14**and the opaque binder **19**. The layer of light transmissive material **128** is activated into the set state in a conventional manner for binding the layer**128** to the beads **14**. Layering the opaque layer **16** and thin transparent layer**15** as illustrated and described herein assures that portions of the incident surfaces **36** of the beads **14** protrude from the opaque binder. The deformable semi-viscous state of the light transmissive beneficially allows the layer to conform to the shapes of these protruding portions

of the beads **14** and retain the shape of defined lenses**131** with centers of curvature forward of the centers of curvature of the beads **14** Radii of curvature of these lenses **131** can also be adjusted in this manner. This process may result in a non-uniform thickness in the layer **128** measured normally to the incident surfaces **36** of the beads **14**. Alternatively, a small quantity of light transmissive material may be centrally deposited on upper crests of the protruding beads **14** prior to depositing the layer **128** of light transmissive material in the unset state on protruding incident surfaces **36** of the beads **14**. The combined volumes of transparent materials on the incident surfaces **36** of the beads **14** migrate together under heat and/or pressure to form the diffusion lenses as previously described on the incident surfaces **36** of each bead **14**.

[0042] In another embodiment of the present invention, the asymmetrical gain of the filter may be enhanced along one axis relative to another orthogonal axis using a structure as partially illustrated in Figure 9. Specifically, the sectional view of the filter illustrated in this figure (i.e., as a top sectional view) shows a layer**399** of prismatic 'lenses' **400** having planar or plateau faces **402** and faceted or angular sloped faces **404**, **406** in iterative, contiguous orientations along, for example, the horizontal axis of the filter. In this embodiment, the layer **399** of prismatic 'lenses' is disposed to receive incident collimated light rays A, B from a light source (not shown). Rays A impinging upon the plateau faces **402** are transmitted through the

layer without deviation, and the dispersion of light via the successive segments of the filter including a beaded layer proceeds as previously described. However, collimated light rays B impinging upon the sloped faces **404, 406** are deviated from the incident orientation (by as much as about 20°) to provide additional dispersion through the successive segments of the filter including a beaded layer as previously described, with resultant wider viewing angle θ_2 along the horizontal axis. The horizontal angle may be adjusted by changing the size of the plateau faces **402** and the angles of the sloping faces **404, 406**. It should be noted that enhanced viewing angle, for example, along the horizontal axis may be so enhanced with the prismatic layer **399** disposed before or after a beaded segment of the filter, and with the prismatic surfaces **402, 404,406** facing in either direction relative to the axis of incident light. Also, the spacing shown between the prismatic layer **399** and beaded segment of filter on support layer 12 is illustrative only, and such spacing may be zero for a contiguous, layered structure.

[0043] Thus, a flat-surface filter structure may be achieved that is conducive to receiving anti-reflective coatings, and the like, using a prismatic layer **399** at the incident or input side of the filter with the prismatic surfaces oriented inwardly. A support layer of the transparent material may be disposed at the output side of the filter, with beaded segments according to previously-described embodiments interposed between such input and output surfaces. Alternatively, the prismatic

layer **399** may also be disposed to receive light output from a beaded segment as previously described, with the sloping faces oriented toward the direction of light output or toward the incident light.

[0044] Variations of the prismatic layer **399** in accordance with alternative embodiments of the present invention are illustrated in the top sectional views of Figures 10 and 11 in which different angles of sloping surfaces may be used to provide enhanced viewing angles along the horizontal axis. Specifically, as shown in the top sectional view of Figure 10, a sloping surface may be formed of two or more surfaces or facets **405, 407** that are disposed at different angles. Alternatively, as illustrated in the topsectional view of Figure 11, the prismatic lenses **400** may be asymmetrical about the plateau faces **402**, with sloping faces **409, 411** at different slope angles on opposite sides of the plateau faces **402**.

[0045] The various configurations of prismatic lenses, for example, as illustrated in Figures 9-11 may be fabricated as microgrooves that are cut or otherwise formed in thermoplastic transparent sheet material , for example, as by embossing with a master platen of the inverse image that is heated and pressed into the surface of the thermoplastic sheet. Typical microgrooves form plateaus**400** of about 50 microns at the base.

[0046] Therefore, asymmetrical viewing angles may be established using filter structures according to the present invention which promote a larger viewing angle

along one axis (e.g., the horizontal axis) in comparison with the viewing angle along an orthogonal (e.g. vertical) viewing axis.

What is claimed is:

1. A light filter comprising:

a first layer of substantially opaque material including front and back surfaces;

a plurality of light transmissive beads disposed in a single-layer array within the first layer of opaque material with first portions of the beads protruding through the front surface of the first layer to receive incident light and with remaining portions of the beads not disposed within the first layer penetrating through the back surface of the first layer of opaque material to form light transmissive apertures therethrough; and

a second layer of light-dispersing material having asymmetrical dispersion characteristics along orthogonal axes, the second layer being disposed relative to the beads and first layer to disperse light incident thereon that is normal to the orthogonal axes for enhancing light transmission within the output angle along one of the orthogonal axes relative to light transmission within the output angle along another of the orthogonal axes.

2. A light filter according to claim 1 in which the second layer is disposed to receive light emanating from the apertures.

3. A light filter according to claim 1 in which the second layer is interposed between incident light and the front surface of the first layer.

4. The light filter according to claim 2 including a layer of transparent lenses overlaying the first portion of beads having radius R protruding through the front surface of the first layer, said layer of lenses including curved surfaces disposed to receive incident light and overlaying the first portion of the beads at selected radii of curvature relative to radius R of the beads.

5. The light filter according to claim 3 in which the second layer includes elongated prismatic lenses oriented along one of the orthogonal axes, and including surfaces oriented normal to incident light and sloping surfaces oriented skewed to incident light, the second layer being interposed between incident light and the first portion of beads protruding from the opaque layer for enhancing light transmission within one output angle along a horizontal axis relative to light transmission within another output angle along the vertical axis.

6. The light filter according to claim 2 in which the second layer includes elongated prismatic lenses oriented in substantial alignment with a vertical axis as one of the orthogonal axes, and including surfaces oriented normal to incident light and sloping surfaces oriented skewed to incident light, the second layer being disposed to receive light emanating from the apertures for enhancing light transmission within one output angle along the horizontal axis relative to light transmission within another smaller output angle along the vertical axis.

7. The light filter according to claim 5 in which the sloping surfaces

include multiple facets at different sloping angles.

8. The light filter according to claim 5 in which the sloping surfaces adjacent the surfaces normal to incident light slope at different angles.

9. A light filter comprising:

a first layer of substantially opaque material including front and back surfaces;

a plurality of light-transmissive, substantially spherical beads disposed in a single-layer array within the first layer of opaque material with first portions of the beads protruding through the front surface of the first layer to receive incident light and with remaining portions of the beads not disposed within the first layer penetrating through the back surface of the first layer of opaque material to form light transmissive apertures therethough;

a support layer of transparent material disposed to receive light emanating through the apertures; and

a prism layer disposed relative to the first portion of the beads and the support layer to disperse light supplied thereto asymmetrically along orthogonal axes, the prism layer including a plurality of aligned prisms each including a plurality of substantially planar surfaces oriented along a substantially vertical axis, the prisms dispersing light passing therethrough within a greater angle along the horizontal axis than along the vertical axis.

10. The light filter according to claim 9 in which the prism layer is a film.

Abstract of the Disclosure

An optical filter includes an array of light-transmissive beads in a matrix of opaque binder that surrounds one portion of the beads to provide light entrances and exit apertures for incident light to pass substantially only through the beads. A transparent layer under the opaque layer may serve to increase the diameter of the exit apertures. A prismatic structure or layer of light-dispersing material that exhibits asymmetrical dispersion of incident light along orthogonal axes is disposed relative to the beads to disperse light within a wider output angle along one of the orthogonal axes than along another of the orthogonal axes.

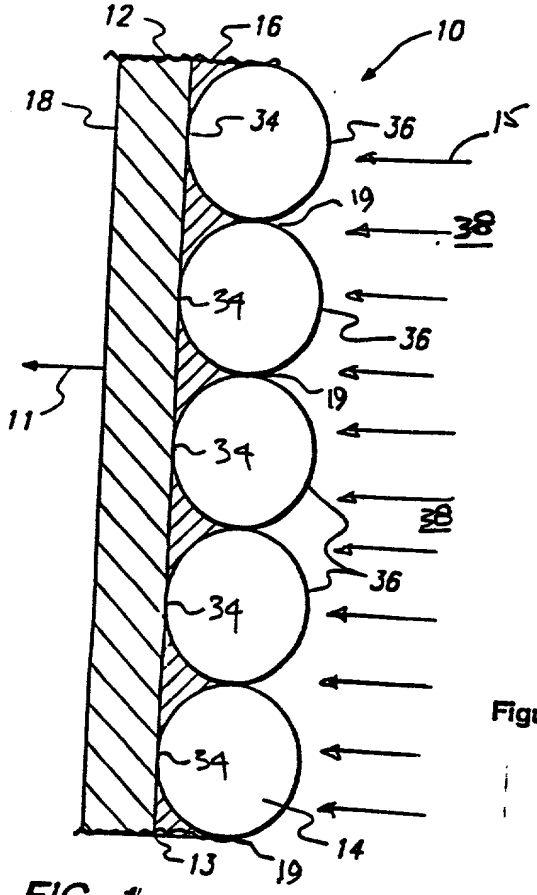

FIG. 1

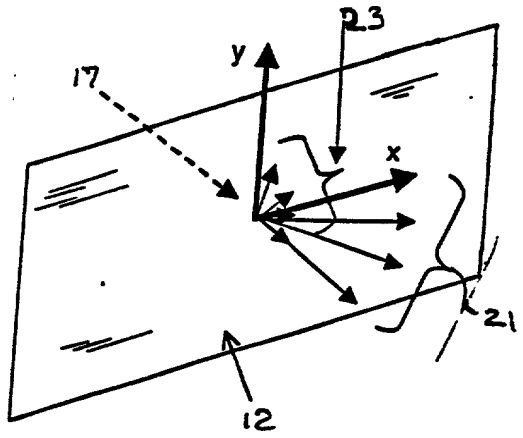

Figure 3

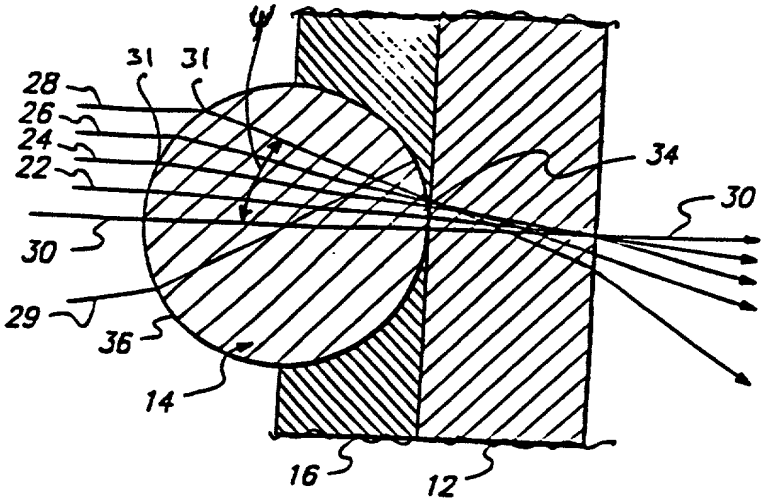

FIG. 2

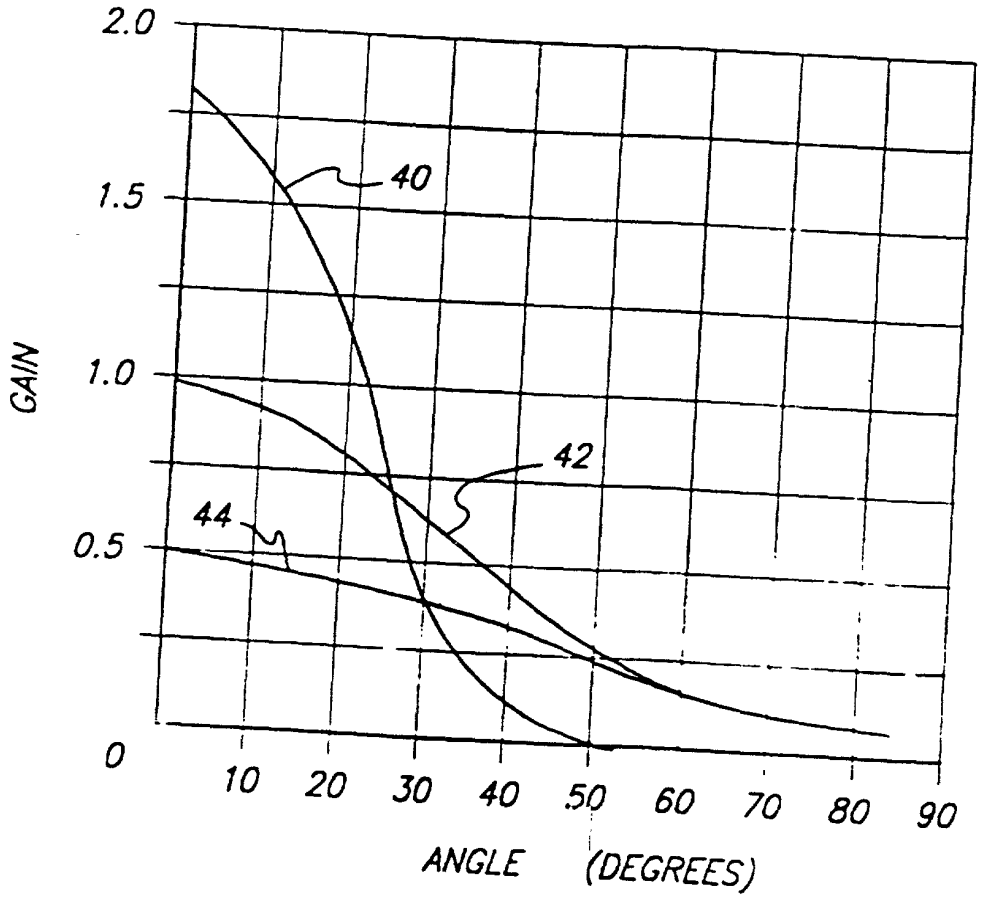

FIG. 4 (PRIOR ART)

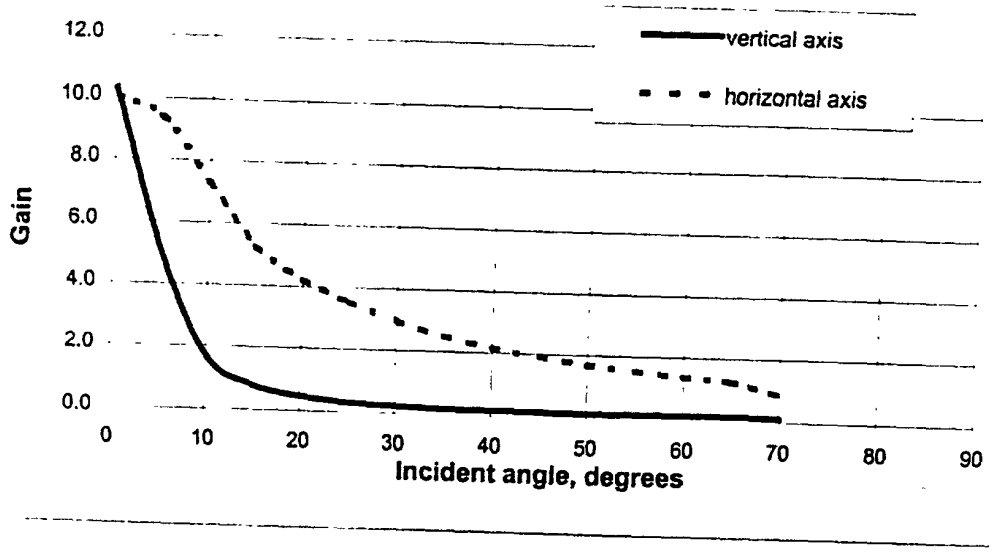

Figure 5

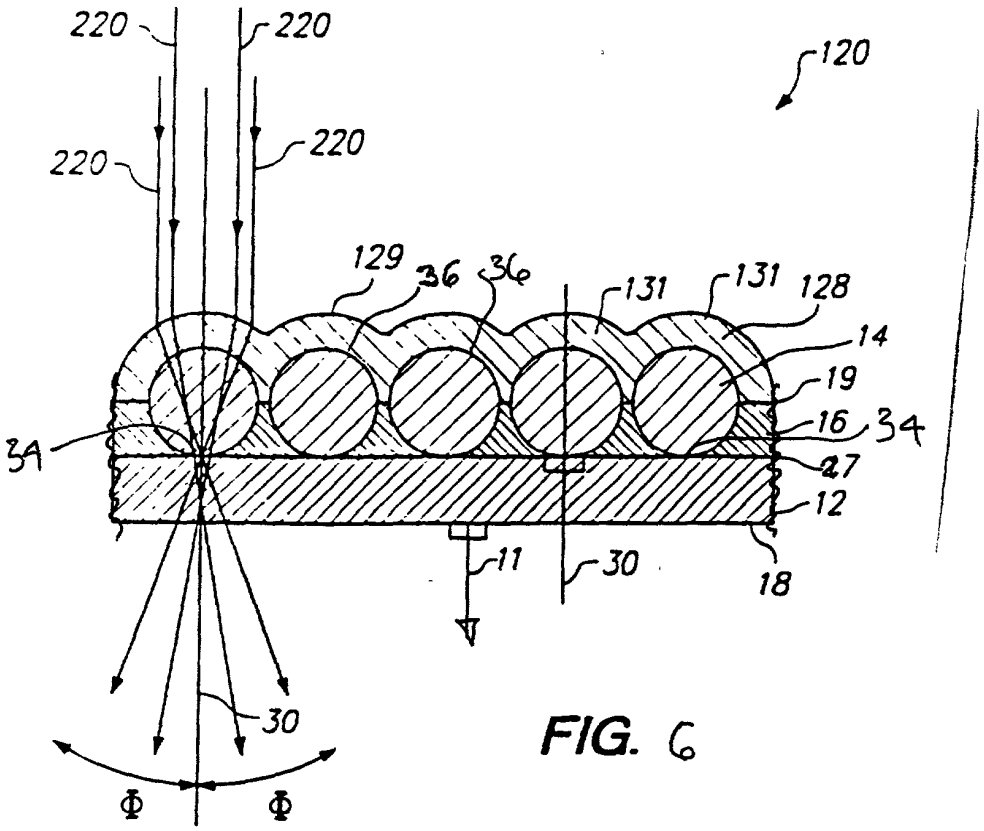

FIG. 6

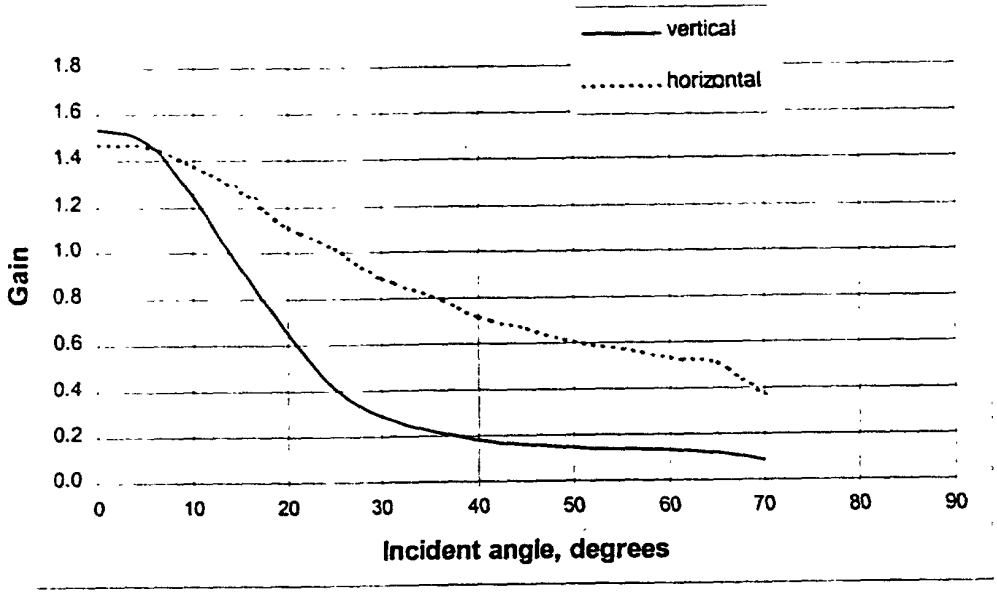

Figure 7

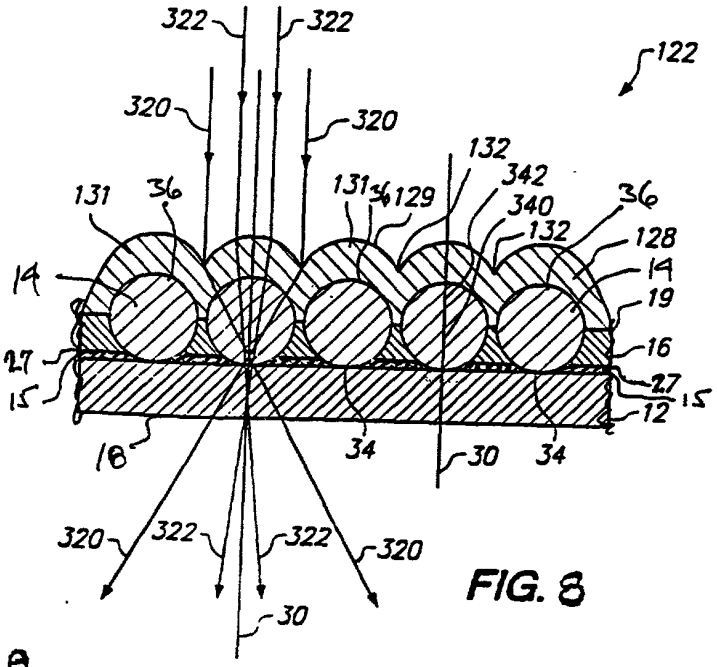

FIG. 8

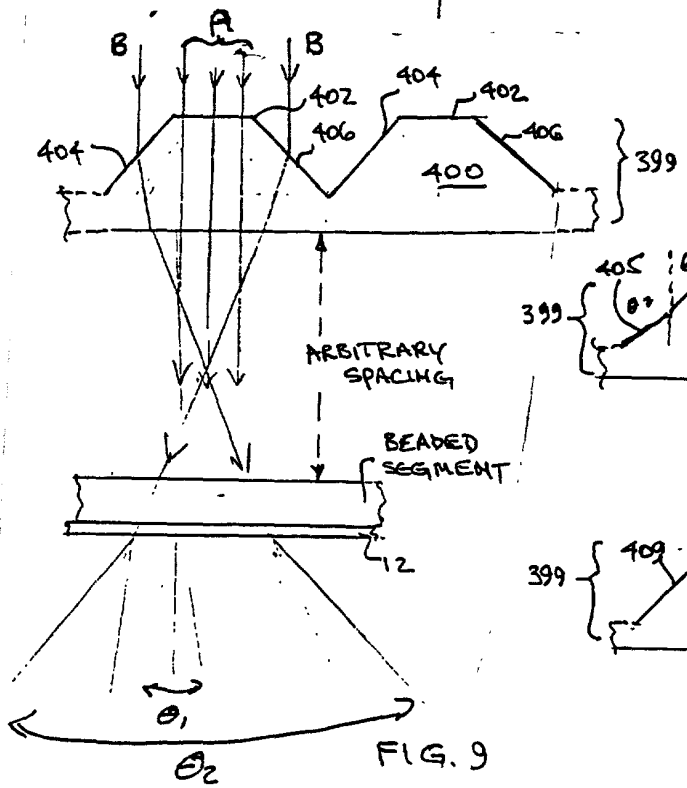

FIG. 9

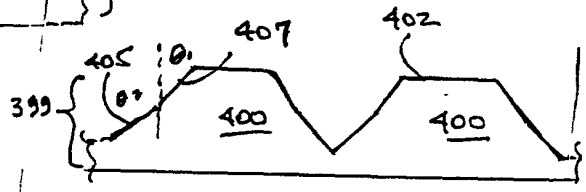

FIG. 10

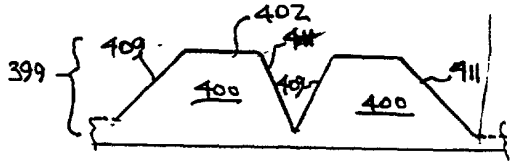

FIG. 11

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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Application Number	Dennis W. Vance
Filing Date	
First Named Inventor	
Group Art Unit	
Examiner Name	
Attorney Docket Number	18590-06192

As the below named inventor(s), I/we declare that:

This declaration is directed to:

☒ The attached application, or

☐ Application No. _____, filed on _____,

☐ as amended on _____ (if applicable);

I/we believe that I/we am/are the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought;

I/we have reviewed and understand the contents of the above-identified application, including the claims, as amended by any amendment specifically referred to above;

I/we acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me/us to be material to patentability as defined in 37 CFR 1.56, including material information which became available between the filing date of the prior application and the National or PCT International filing date of the continuation-in-part application, if applicable; and

All statements made herein of my/our knowledge are true, all statements made herein on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001, and may jeopardize the validity of the application or any patent issuing thereon.

FULL NAME OF INVENTOR(S)

Inventor one: Dennis W. Vance Citizen of: U.S.A.

Signature: Dennis W. Vance Date: 12/28/01

Inventor two: Charles Robert Wolfe Citizen of: U.S.A.

Signature: _____ Date: _____

Inventor three: _____ Citizen of: _____

Signature: _____ Date: _____

Inventor four: _____ Citizen of: _____

Signature: _____ Date: _____

☐ Additional inventors are being named on _____ additional form(s) attached hereto.

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☐ as amended on _____ (if applicable);

I/we believe that I/we am/are the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought;

I/we have reviewed and understand the contents of the above-identified application, including the claims, as amended by any amendment specifically referred to above;

I/we acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me/us to be material to patentability as defined in 37 CFR 1.56, including material information which became available between the filing date of the prior application and the National or PCT International filing date of the continuation-in-part application, if applicable; and

All statements made herein of my/our knowledge are true, all statements made herein on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001, and may jeopardize the validity of the application or any patent issuing thereon.

FULL NAME OF INVENTOR(S)

Inventor one: Dennis W. Vance Citizen of: U.S.A.

Signature: _____ Date: _____

Inventor two: Charles Robert Wolfe Citizen of: U.S.A.

Signature: Charles Robert Wolfe Date: 12/20/01

Inventor three: _____ Citizen of: _____

Signature: _____ Date: _____

Inventor four: _____ Citizen of: _____

Signature: _____ Date: _____

☐ Additional inventors are being named on _____ additional form(s) attached hereto.

Please type a plus sign (+) inside this box → [+]

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POWER OF ATTORNEY OR AUTHORIZATION OF AGENT

Application Number	
Filing Date	
First Named Inventor	Dennis W. Vance
Title	
Group Art Unit	
Examiner Name	
Attorney Docket Number	

I hereby appoint:

☐ Practitioners at Customer Number 00758 →

OR

☒ Practitioner(s) named below:

Name	Registration Number
Albert C. Smith	20,355
Michael W. Farn	41,015

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☒ Applicant/Inventor ***OR*** ☐ Assignee of record of the entire interest. See 37 CFR 3.71.
Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96).

SIGNATURE of Applicant or Assignee of Record

Name	Dennis W. Vance
Signature	Dennis W. Vance
Date	12/28/01

I am the:

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Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96).

SIGNATURE of Applicant or Assignee of Record

Name	Charles Robert Wolfe
Signature	
Date	

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below*.

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First Named Inventor	Dennis W. Vance
Title	
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Name	Charles Robert Wolfe
Signature	Charles Robert Wolfe
Date	12/20/01

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